the Energy to Lead

Integrated CHP Using Ultra-Low-NOx Supplemental Firing

> ***Final meeting***
> *California Air Resources Board*
> *Sacramento, California*

> May 4, 2010

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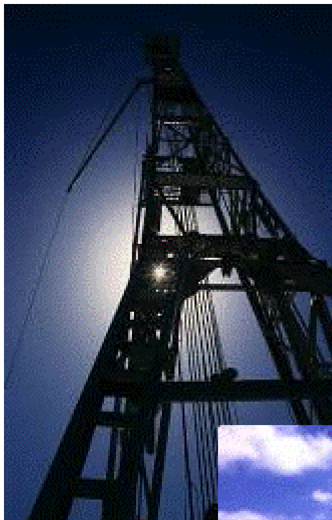
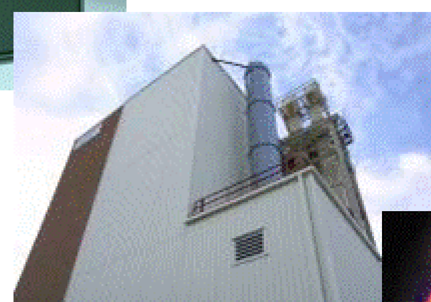
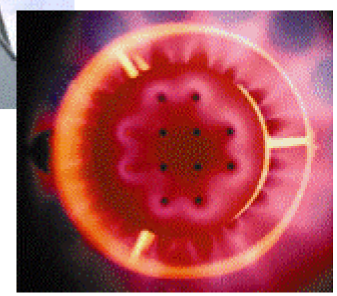
Gas Technology Institute



Addressing Key Issues for the Energy Industry

- > Contract Research
- > Program Management
- > Technical Services
- > Education and Training





- > Over 1,000 patents
- > Nearly 500 products commercialized

Facilities and Staff

Facilities:

- 18-acre main campus
- 28 specialized laboratories (280,000 ft^2)
- Pilot scale gasifier
- Pipe test farm
- 80 acre drilling test facility (OK)
- Offices in Washington DC, Houston, Birmingham

Flex-Fuel Test Facility

Offices and Labs

Energy and Environmental Technology Center

Staff of 250:

- 70% are scientists and engineers

Efforts aligned with the industry value chain

SUPPLY	DELIVERY	CONSUMER

Needs

Secure, stable, competitive energy supply	Expand and maintain infrastructure	Improve affordability and applicability

Strategic Focus

• Unconventional gas resources • Gasification for alternative supply	• Safety • Pipeline integrity • Cost reduction • Efficiency	• Product development and commercialization

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Overview

- Objectives and Approach
- Technology Description
- Lab-Scale Development
- Scale-up
- Field Test Site
- Next Steps

Origin of the Project

Problem

- Combined heat and power (CHP) systems based on gas turbines save energy and $$$ for gas users, BUT...
  - Exhaust losses are relatively high due to high excess air required for turbine
  - Supplemental burners can reduce the exhaust loss but add more NOx
  - Current supplemental burners are challenged to meet the 2007 Fossil Fuel Emissions Standard for turbines *0.07 lb NOx per MWh total output*

There is a Need to Develop . . .

> Integrated CHP packages that match
  – A power generator (turbine)
  – A low emission supplemental burner
  – A waste heat user (boiler)

> To improve energy efficiency and meet clean air requirements

> An advanced burner
  – Very low emissions . . . even with high-temperature turbine exhaust gas (600-1100°F) as an oxidant

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Benefits to ARB Program

- Promotes the development, commercialization, and use of zero- and near-zero emission technologies
- Helps ARB fulfill its stated mission "to promote and protect public health, welfare and ecological resources through the effective and efficient reduction of air pollutants while recognizing and considering the effects on the economy of the state"

Benefits

> Enhance market acceptance of CHP
  – Save many $$$ for gas customers
  – Smog mitigation through NOx reduction
  – Widely recognized as a potential means of increasing energy efficiency
  – A cost-effective means of satisfying the steam needs of a wide variety of facilities – an alternative to SCR

> Californians
  – Lower energy costs through the more efficient use of natural gas
  – Increased security of electricity supply through on site generation
  – Improved environmental quality

Objectives and Approach

Two Objectives

> Innovative burner development
  – Cultivate promising R&D results
  – Obtain industry support
> Pre-engineering of a cost-effective CHP package
  – Employ state-of-the-art technology
  – Enlist a strong project team
  – Bring technology to the market

Project Goal and Objectives

> Goal
  - Develop a cost-effective gas turbine based CHP system that improves overall efficiency and meets 2007 Fossil Fuel Emissions Standard without catalytic exhaust gas treatment

> Objectives
  - Achieve 84% (HHV) system efficiency
  - Generate a pre-engineered cost-effective CHP package employing state-of-the-art design concepts
  - Validate the system in the GTI laboratory
  - Demonstrate the system at a end-user site

Performance Targets

- Develop a novel supplemental burner for conventional turbines and microturbine-based CHP applications
- Integrate the burner into a cost-effective CHP package that improves overall efficiency and meets 2007 Fossil Fuel Emissions Standard without SCR
- Performance goals:
  - 84% HHV system efficiency
  - <0.07 lb/MWh NOx
  - 4 to 1 turndown

Project Team

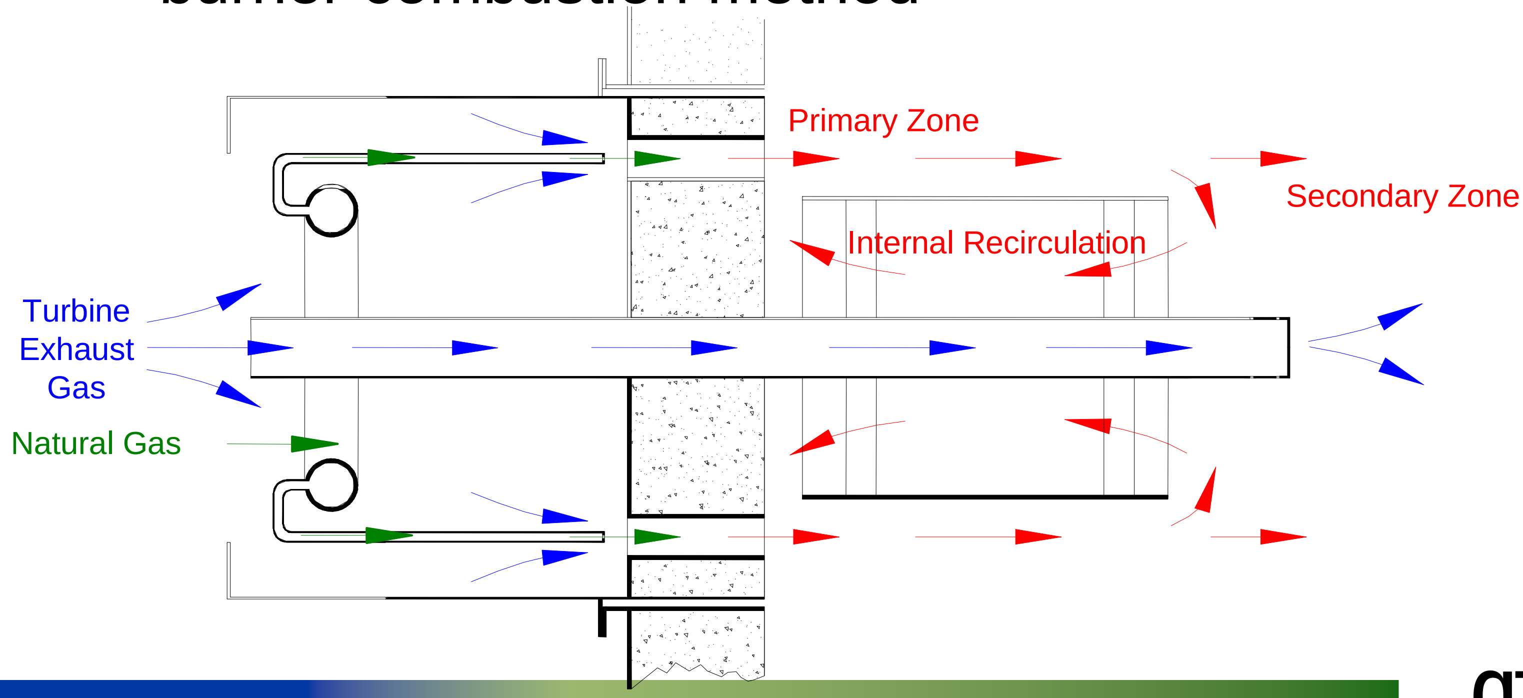
- Performing organizations
  - Gas Technology Institute
  - Integrated CHP Systems Corporation
  - Accu Chem Conversion, Incorporated
- Sponsors
  - California Air Resources Board
  - California Energy Commission
  - Utilization Technology Development NF
  - Gas Research Institute

Technology Description

Technology . . .

> Supplemental Ultra-Low-NOx (ULN) burner features

- Based on forced internal recirculation (FIR) burner combustion method



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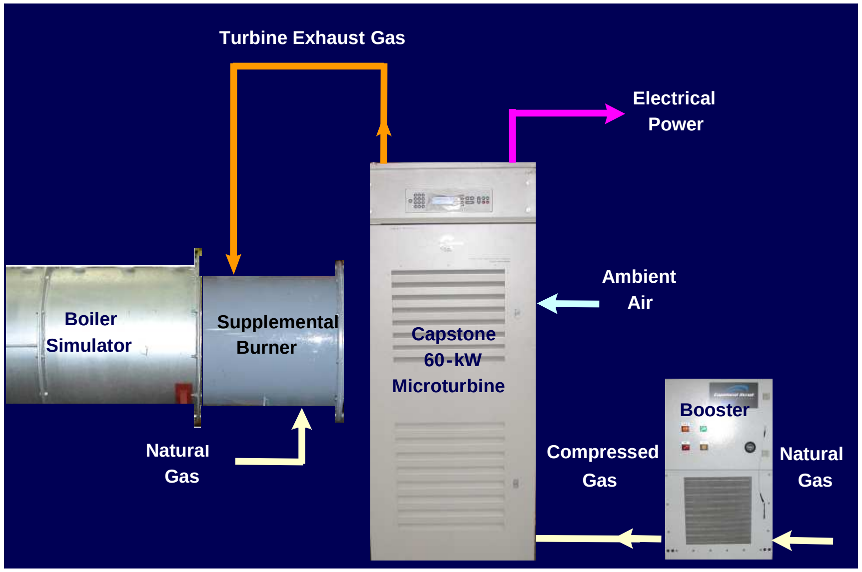
And Innovation . . .

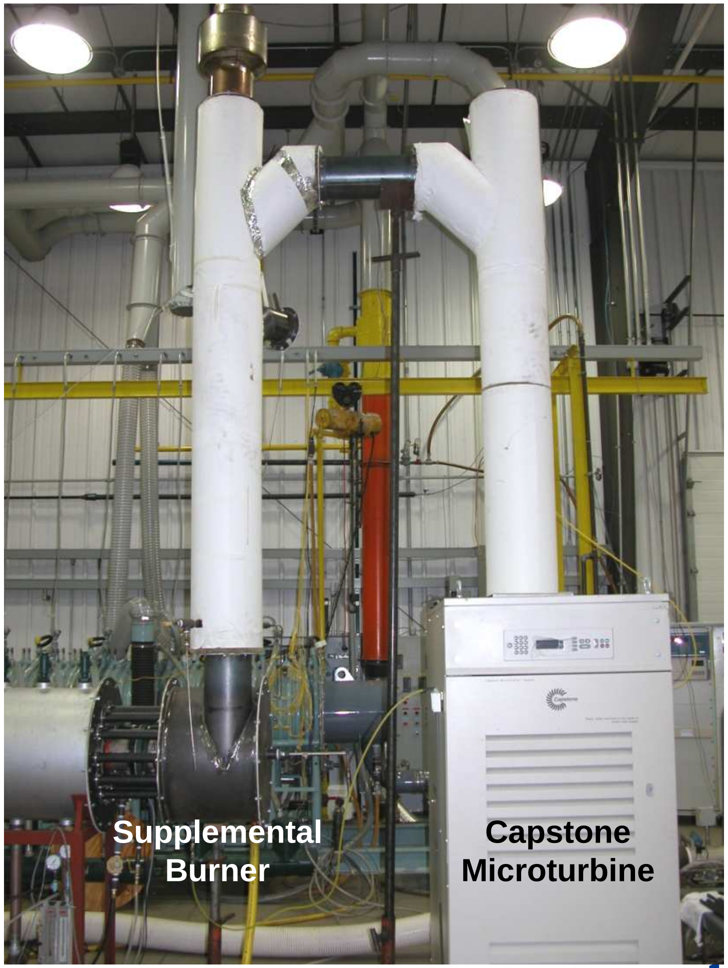
> Supplemental ULN burner features
  - Less than three inches wc burner pressure drop
  - Targeted for boilers and absorption chillers
  - Significant thermal energy added to the turbine exhaust gas
  - No blower required
  - No augmentation air requirement



Lab-Scale Development

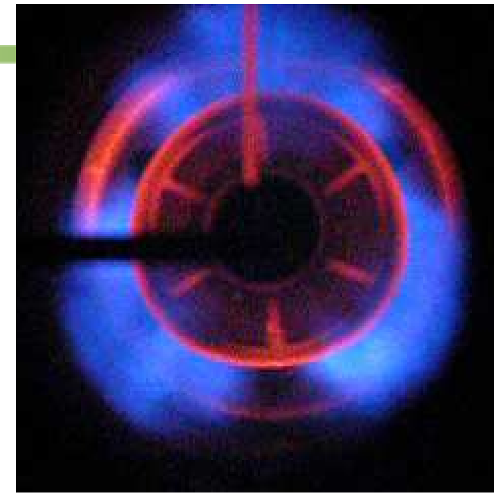
Supplemental ULN Burner Integrated with Microturbine

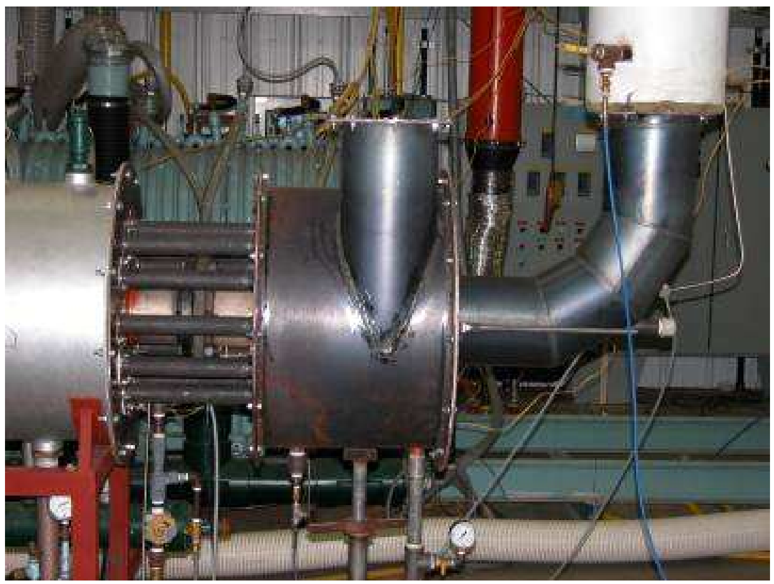
> Advanced burner technology for CHP systems
  - Capstone 60-kW microturbine
    - 17.8% O_2
    - 3.4 vppm NOx
    - 9 vppm CO
    - 610°F
    - 6 in wc
  - Increases CHP efficiency
  - Reduces emissions



ULN Supplemental Burner Technology

- **>** Breakthrough design
  - Part of FIR family





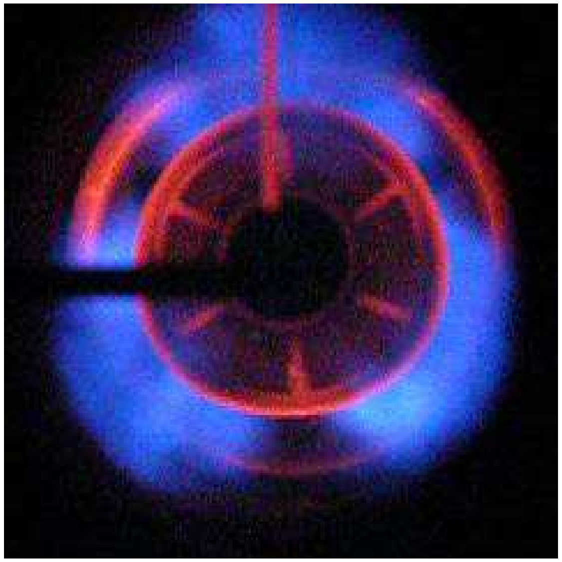
FlexCHP-60 Lab Performance

	Microturbine	Microturbine + Supplemental ULN Burner
Turbine Output, kW	50	50
Burner Heat Input, million Btu/h	--	2.11
O_2, vol%	17.8	8.1
NOx, vppm	3.4	2.2
CO, vppm	9	5
NOx Reduction, %	--	35.2

- Reduces NOx in exhaust
- Reduces excess air
- Lab tests show 35 - 48% NOx reduction compared to raw turbine exhaust

Supplemental Burner for CHP

> Laboratory results
  - With unmodified Capstone TEG, NOx reduced 35%
  - With NOx doping (46 vppm) to simulate an older turbine, NOx reduced 70%
  - CO below 10 vppm in all cases



Scale-up

Scale-Up

- Scale-up issues
  - Cost
  - Emissions
  - Velocities and pressures drops
  - Utilization of existing components
  - What is common market size?
  - What demonstration sites are available?

STEG Generation

- Investigated various approaches to generate simulated turbine exhaust gas (STEG) in laboratory
  - Up to 20% of a Solar Mercury 50 output

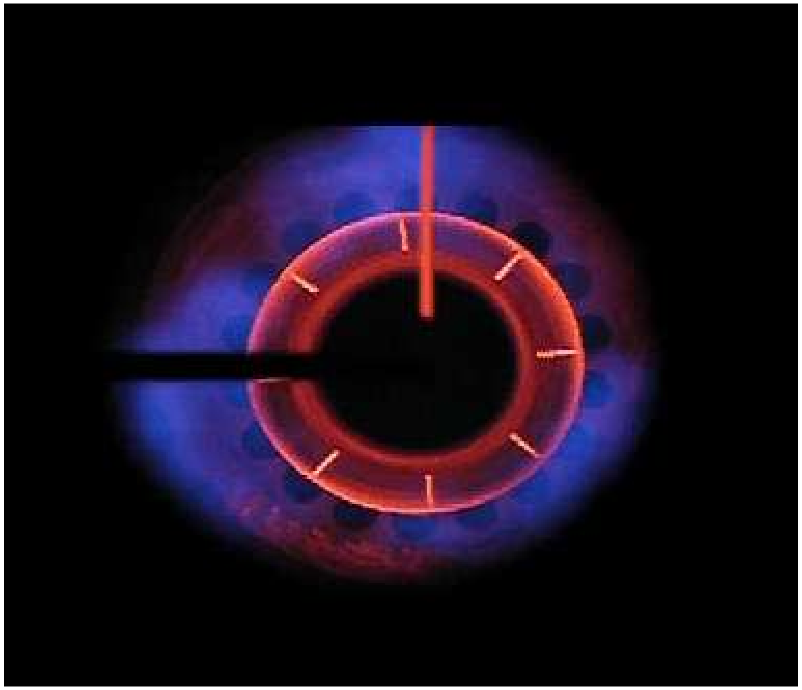
Summary of Mercury 50 Emissions Data				
Turbine Load, %	**25**	**50**	**75**	**100**
Exhaust Temperature, ºF	**637**	**666**	**681**	**705**
Oxygen Content Dry Based, %	**17.8**	**17.2**	**16.7**	**16.4**
Carbon Dioxide Dry Based, %	**1.8**	**2.2**	**2.4**	**2.6**
NOx Content, vppm	**--**	**5**	**5**	**5**

Supplemental ULN Burner 7.5 million Btu/h Capacity

Supplemental ULN Burner

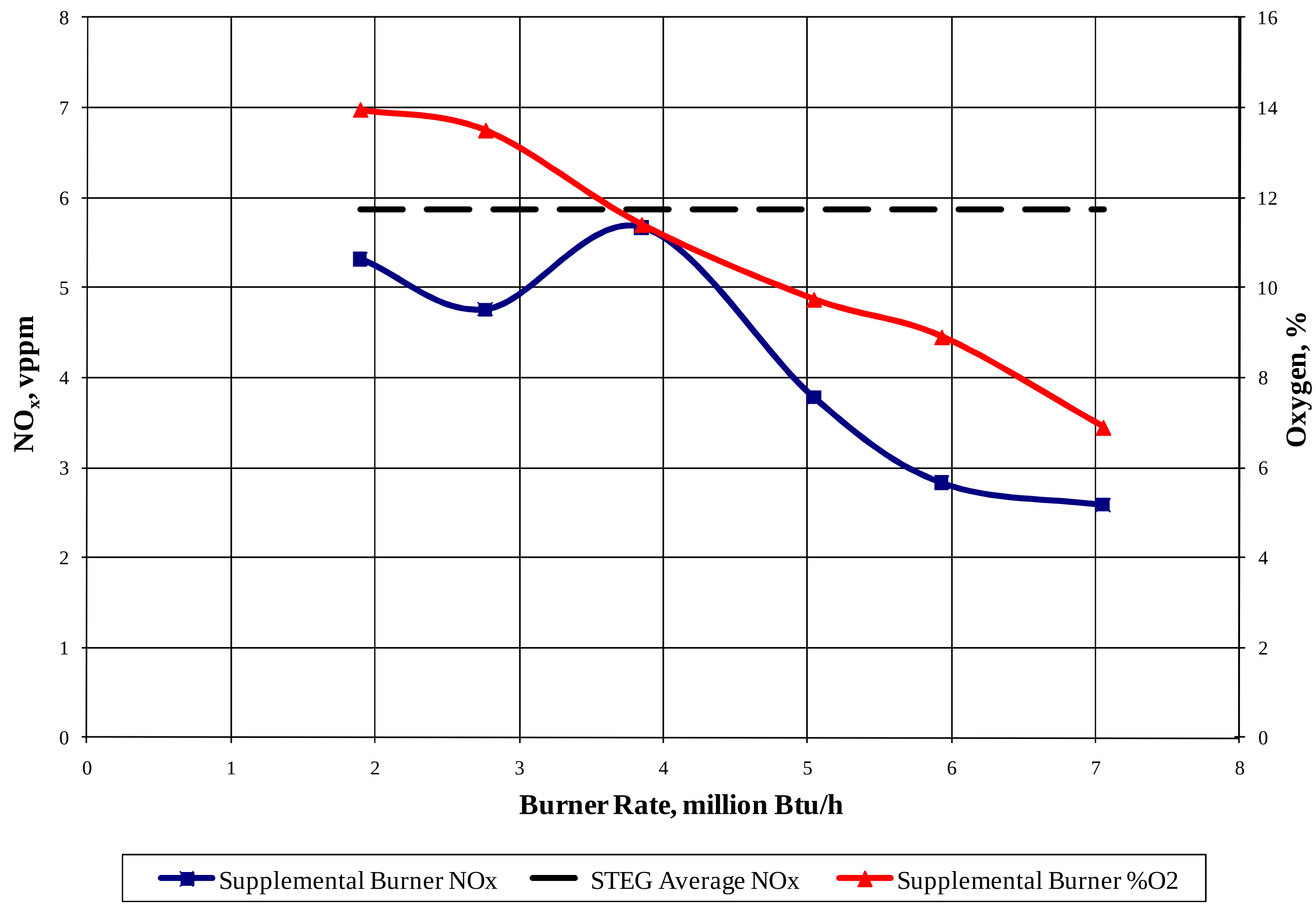
Auxiliary Burner

Burner Flame



7.06 million Btu/h
STEG NOx 5.0 vppm
Stack NOx 2.4 vppm

Supplemental ULN Burner
Gas Turbine Load 100%



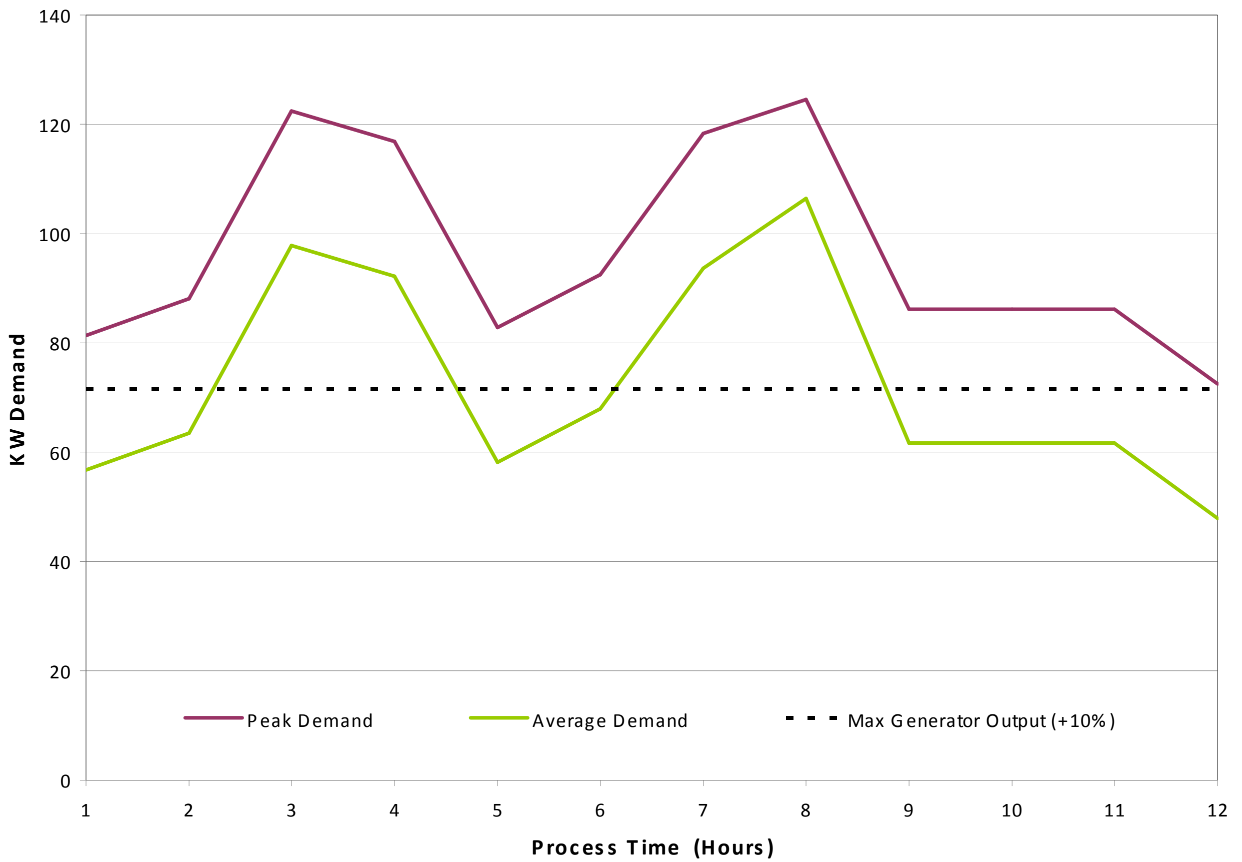
Field Test Site

Accu Chem Conversion, Inc.

Trans-Loading Facility

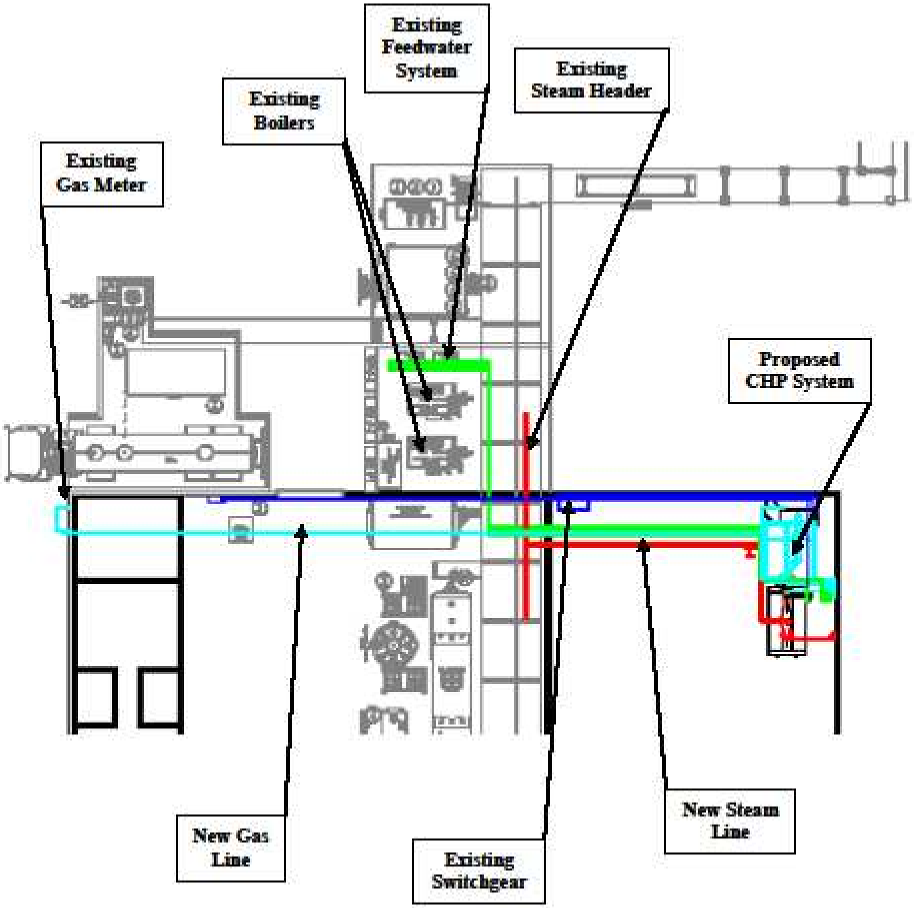
Biodiesel Refinery

Representative Electrical Profile



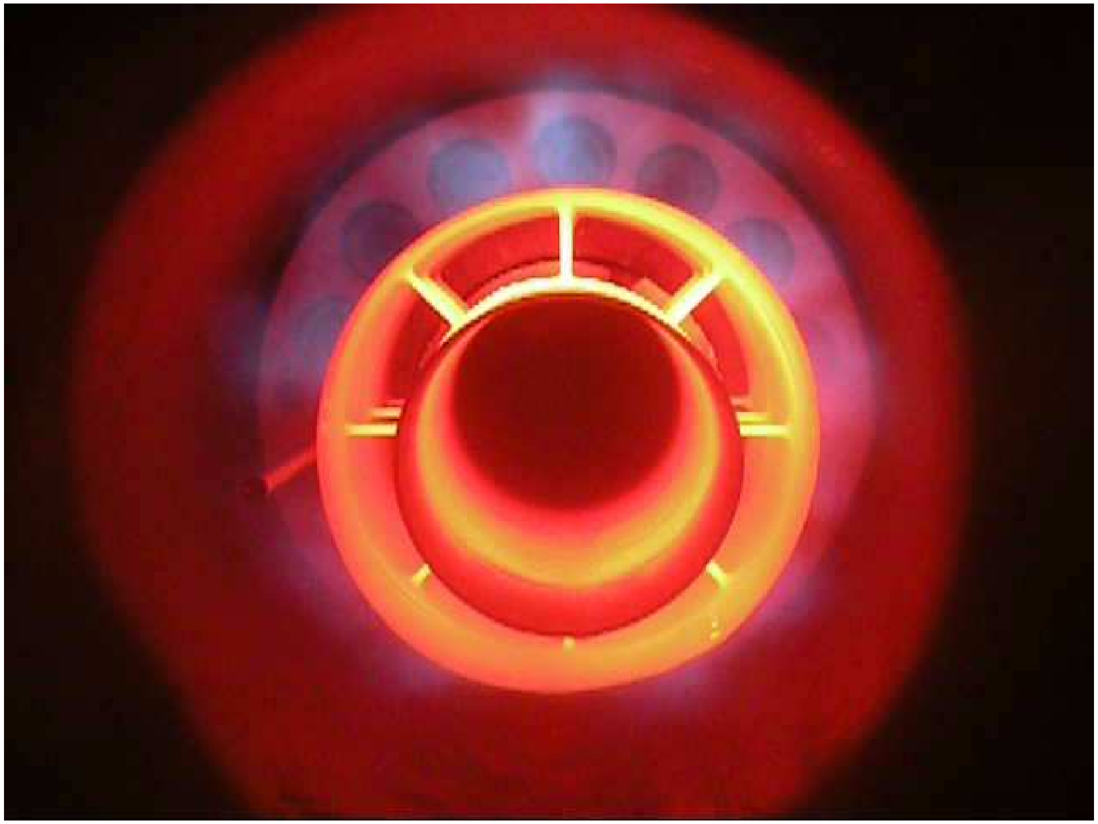
12-Hour Batch

CHP Plant Layout

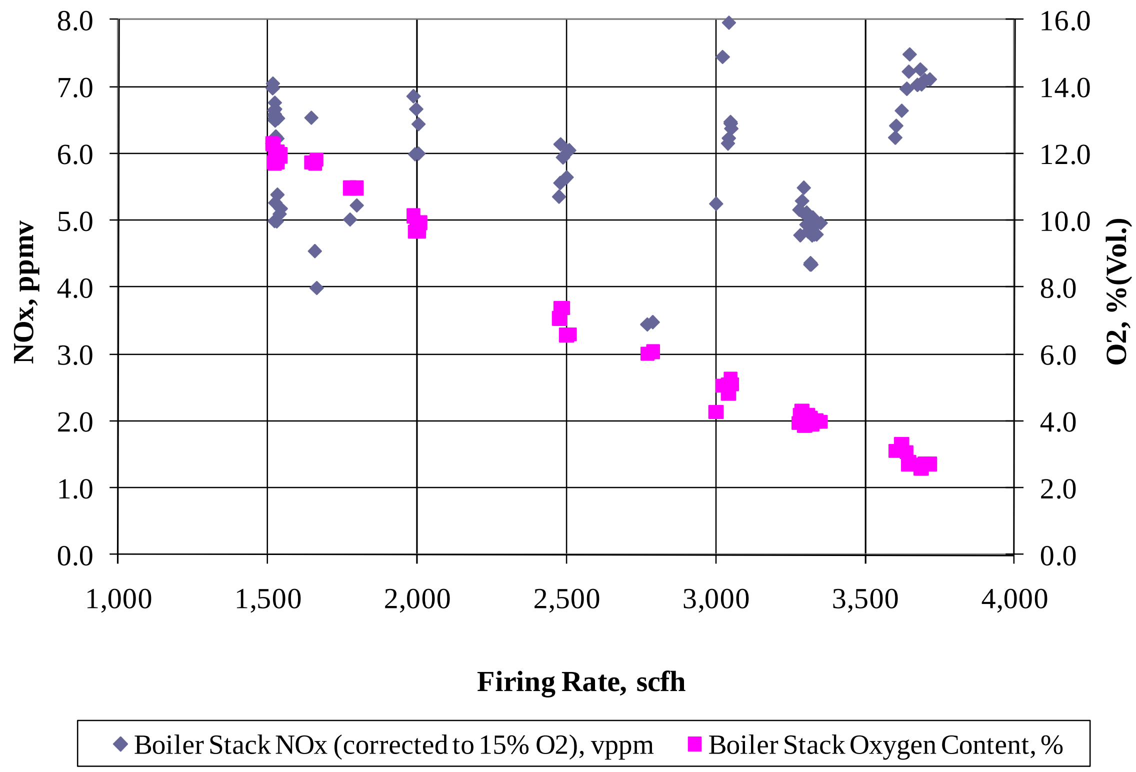


FlexCHP-65
4 million Btu/h Capacity

FlexCHP-65
3 million Btu/h



Emissions over Firing Rate



Next Steps

Project Plan

- The project will be completed to its natural conclusion with co funding from other sponsors
  - Complete performance testing based on the Final Laboratory Performance Test Plan
  - Install and evaluate the FlexCHP-65 system at end-user site
  - Technology transfer and commercialization readiness activities

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Creating technology solutions with **impact** across the **energy** spectrum

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